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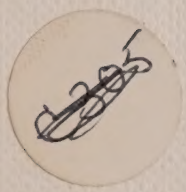
OPERATION AND SERVICE MANUAL

FOR

STANDING WAVE AMPLIFIER

GMC TYPE 351



VIKING LABORATORIES INC.

GENERAL MICROWAVE
CORPORATION
155 MARINE STREET · FARMINGDALE, L. I.

OPERATION AND SERVICE MANUAL

FOR

STANDING WAVE AMPLIFIER

GMC TYPE 351

GENERAL MICROWAVE CORPORATION

FARMINGDALE, NEW YORK

VIKING LABORATORIES INC.

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SECTION 1 - INTRODUCTION

1.1 GENERAL

The Standing Wave Amplifier, GMC Type 351 (figure 1) is a direct-reading instrument which measures VSWR and attenuation ratios when used with square-law detectors of either the crystal or bolometer type. The detector is usually mounted in a probe to detect power levels in a slotted section for VSWR measurements or in a waveguide or coaxial mount for attenuation measurements. The Standing Wave Amplifier comprises a six stage, narrow-band, audio amplifier; a meter circuit, and a power supply. The gain of the amplifier is controlled from the front panel; a recorder can be connected to the amplifier if a permanent record of meter indications is desired.

1.2 SPECIFICATIONS

The specifications for the Standing Wave Amplifier are listed in Table 1.

Table 1
Specifications

FREQUENCY:	1000 cps ± 2%
SENSITIVITY:	0.1 uv at a 200 ohm level for full scale detection.
NOISE LEVEL:	Less than 0.03 u v ref. to input operated from a 200 ohm resistor at room temperature.
AMPLIFIER Q:	25 ± 5.
CALIBRATION:	Square law. Meter indicates SWR, db.
RANGE:	70 db. Input attenuator provides 60 db in 5 db steps. Accuracy ± 0.1 db per 10 db. Maximum cumulative error ± 0.2 db.
SCALE SELECTOR:	"Normal", "Expand", and "Bolometer Current".

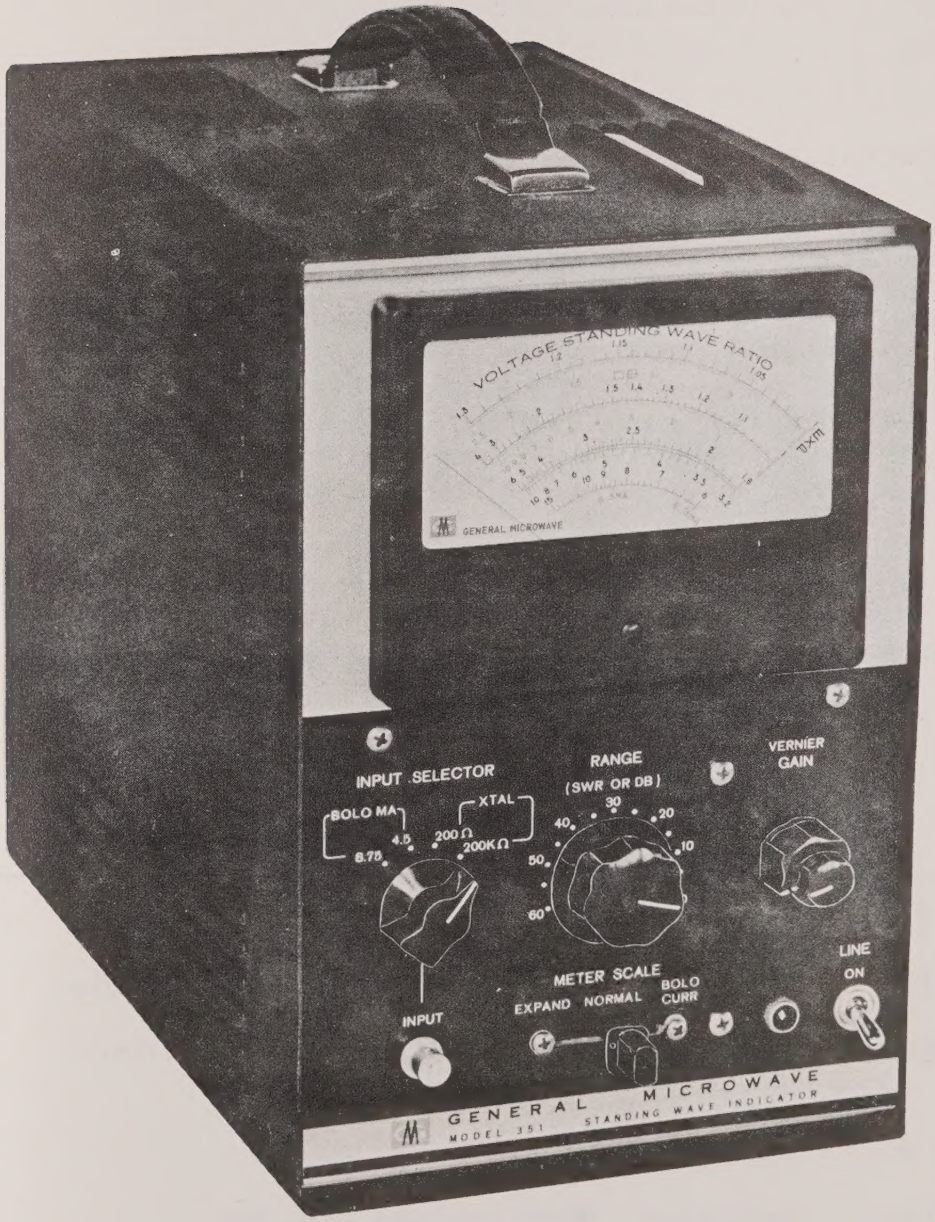

FIGURE 1 GMC TYPE 351 STANDING WAVE AMPLIFIER

METER SCALES:	SWR 1-4, SWR 1.8-6, SWR 3.2-10, SWR 6-15 Expanded SWR 1-1.3, db 0-10, Expanded db 0-2.3, Bolometer Current 4.5 and 8.75 ma.
GAIN CONTROL:	Adjusts to convenient reference level. Range at least 10 db.
INPUT:	"Bolo" (200 Ω). Bias provided for 8.75 ma bolometer or 1/100 amp fuse; or 4.5 ma low current bolometer.
	"Crystal".
	"200Ω" for crystal rectifier.
	"200,000Ω". High impedance for crystal rectifier as null detector.
RECORDER OUTPUT:	Jack provided for recording milliammeter having 1 ma full scale deflection, internal resistance of 1500 ohms or less.
INPUT CONNECTOR:	BNC
POWER:	115/230 volts ± 10%, 50 to 60 cps, 55 watts.
DIMENSIONS:	Cabinet Mount: 7 1/2" w x 11 1/2 h x 14" d.
WEIGHT:	Cabinet Mount: 15 pounds.

SECTION II

OPERATION

2.1 PREPARATION FOR USE

The Standing Wave Amplifier is shipped completely assembled and ready for use. After inspecting for possible shipping damage, connect the line plug to a source of 115 volt ±10 percent, 50 to 60 cps ac. For operation from a 230 volt power source, the dual 115 volt primary windings on the power transformer are connected in series. Refer to the schematic diagram for proper connections. After converting the instrument, change the power line fuse to the size specified in the Table of Replaçeable Parts (Section IV) for 230 volt operation.

2.2 CONTROLS AND TERMINALS

The purpose of each operating control, indicator, and connector mounted on the front and rear panels is listed in Table 2.

Table 2

Purpose of Controls, Indicators, and Connectors

ON-OFF switch:	Controls the a-c voltage applied to the amplifier.
INPUT SELECTOR switch:	Connects the input circuits for 4.5 or 8.75 ma bolometers, crystal, or high impedance detectors.
METER SCALE switch:	Connects the meter circuits for regular or expanded scale VSWR and attenuation measurements or for bolometer current measurement.
RANGE switch:	Adjusts amplifier gain in calibrated 5 db steps between 0 and 60 db (0 db provides maximum gain).
GAIN control:	Varies amplifier gain continuously over a 12.5 db range. This control is not calibrated.
INPUT connectors:	Connects the detector to the amplifier circuits.

VOLTAGE STANDING WAVE RATIO meter:	Indicates VSWR, attenuation, or bolometer current depending on the position of the SCALE switch.
Pilot lamp:	Lights when a-c voltage is applied to the unit and the ON-OFF switch is ON.
RECORDER connector:	Connects an external recorder in series with the meter.
3AG 1 AMP fuse:	Protects the unit against electrical overloads.

2.3 TYPICAL OPERATING PROCEDURE

2.3.1 TECHNIQUES IN SWR MEASUREMENTS

Basically, the measurement of a standing-wave ratio consists of setting the probe carriage of a slotted line at a voltage maximum position and setting the gain of the Model 351 to obtain a reading of 1.0. The probe carriage is then moved along the slotted line to a voltage minimum and the VSWR is indicated directly on the scale of the Model 351. This method, while straightforward and simple, may lead to serious errors under certain conditions. Paragraph 2 through 4 discuss these errors and suggest techniques for minimizing their effects. In many cases, only a knowledge of the SWR is required, but there are other cases, chiefly in design and development, where complete knowledge of the terminating equipment is desired. This can be obtained by measuring SWR and phase in the standing-wave pattern.

Generally, the impedance characteristic of the load is obtained by measuring the position of the voltage minimum. This position is compared to a shifted position of the voltage minimum which occurs when a known load replaces the load under test at a reference point on the slotted line. For convenience, the known load is usually a short circuit or shorting plate and the reference point is the load connection. The distance between these two minima is entered on a Smith Chart and the reactive component is determined. Detailed instructions for measuring the impedance characteristics of the load are generally given in slotted line instruction books or books on microwave measurements (1).

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(1) See "Handbook of Microwave Measurements", Edited by M. Wind and H. Rapaport, Sect. II, Polytechnic Press, Polytechnic Institute of Brooklyn, 1954.

2.3.2 DETECTOR PROBE PENETRATION

A general rule in slotted line work is that the penetration of a sampling probe into the line should be held to a minimum. One of the major sources of error in VSWR measurements is the failure to observe this rule.

The power extracted by the sampling probe causes distortion in the standing-wave pattern. This effect usually becomes greater as probe penetration is increased and can be explained by considering the probe as an admittance shunting the line.

Impedance in the standing-wave pattern varies along the line from maximum at a voltage maximum to a minimum at a voltage minimum. The shunt admittance introduced by the probe lowers these impedances, thus causing the measured VSWR to be lower than the true VSWR and shifting both the maxima and minima from their natural positions. The shift will be greater at a voltage maximum than at a voltage minimum.

Besides absorbing power and affecting the standing-wave pattern, the probe will also cause reflections in the line. These reflections will travel towards the signal source. If the signal source is not matched, these reflections are re-reflected toward the load and will cause additional errors in low VSWR measurements.

An exception to the minimum penetration rule occurs when it is desired to examine in detail a voltage minimum in high VSWR measurement. For this work, greater probe penetration can be tolerated because the voltage minimum corresponds to a low impedance point in the line. However, only at a voltage minimum can you tolerate substantial probe penetration.

2.3.3 PRECAUTIONS WHEN USING CRYSTAL DETECTORS

With a crystal detector, select the input impedance which gives maximum sensitivity. Usually, the 200 ohm position will give the best sensitivity. However, some crystal diodes may give higher output in the 200K ohm position. Maximum sensitivity is desirable so probe penetration in the slotted line can be kept to a minimum.

There are precautions to be observed concerning all crystal detector elements. Crystal diodes exhibit a departure from the ideal square-law response for which the 351 is calibrated. This departure tends to occur when the rf power level exceeds a few microwatts. This corresponds to a reading of approximately full scale on the 30 db range of the 351 with the gain controls set to maximum.

2.3.4 VSWR MEASUREMENTS

VSWR is measured by first adjusting the probe to a point of maximum voltage along the slotted section and setting the VOLTAGE STANDING WAVE RATIO meter to a full scale deflection. Next, the probe is adjusted to a point of minimum voltage along the slotted section. The meter now indicates VSWR directly. To perform a VSWR measurement, starting with the unit connected to a source of a-c voltage, proceed as follows:

a. Connect the equipment to the Standing Wave Amplifier as shown in figure 2.

b. Place the INPUT SELECTOR switch in the position corresponding to the detector being used.

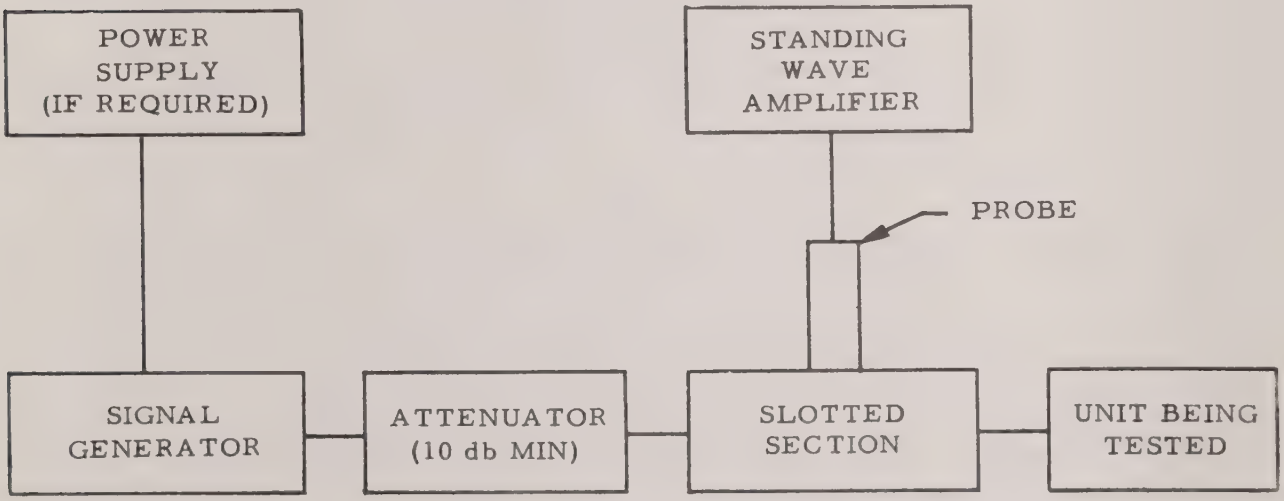

Figure 2. VSWR Measurement Setup

CAUTION

If the INPUT SELECTOR switch is in the BOLO MA 8.75 position when a 4.5 ma bolometer is being used, the bolometer will be destroyed by excessive current.

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c. Place the METER SCALE switch in the NORMAL position and the RANGE switch in the 60 position.

d. Place the ON-OFF switch in the ON position. Wait about five minutes for the unit to warm up before making any measurements.

e. Set up the oscillator for the desired signal frequency with 1000 cps square-wave modulation.

f. Adjust the RANGE switch until an indication is obtained on the meter.

NOTE

During the following procedure, it will be necessary to adjust the RANGE switch to keep the meter indication on scale.

g. Adjust the probe position until a maximum indication is obtained on the meter.

h. Adjust the oscillator modulation frequency until a maximum indication is obtained on the meter.

i. Adjust the RANGE switch and the GAIN control to get a full scale (VSWR = 1) indication on the meter.

j. Adjust the probe position until a minimum indication is obtained on the meter. Note the total required change in the position of the RANGE switch.

k. The meter indicates VSWR directly. If the RANGE switch has not been adjusted, read the VSWR from the 1 to 4 scale. If the RANGE switch has been adjusted, use the lower scales on the meter. Move down one scale for each step that the RANGE switch has been moved. Table 3 lists the scale to be used for several changes in RANGE switch position.

Table 3

VSWR Values for RANGE Switch Positions

Clockwise Change in RANGE Switch Position (DB)	Use Scale	Range of Values
0	1 to 4	1 to 4
5	1.8 to 6	1.8 to 6
10	3.2 to 10	3.2 to 10
15	6 to 15	6 to 15
20	1 to 4	10 to 40

1. If the indicated VSWR is less than 1.3, turn the METER SCALE switch to the EXPAND position. The VSWR is read from the EXPAND meter scale (1 to 1.3).

2.3.5 ATTENUATION MEASUREMENT

To perform an attenuation measurement, starting with the unit connected to a source of a-c voltage, proceed as follows:

a. Connect the attenuation-measurement as shown in figure 3. Do not connect the unknown attenuator at this point in the procedure. Select the desired signal frequency and adjust the modulation for 1000 cps square wave amplitude modulation.

b. Measure the VSWR of the detector as described in paragraph 4 above. Adjust the tuner until the VSWR has been reduced to an acceptable value.

c. Place the INPUT SELECTOR switch in the position corresponding to the detector being used for attenuation measurements.

CAUTION

If the INPUT SELECTOR switch is in the BOLO MA 8.75 position when a 4.5 ma bolometer is being used, the bolometer will be destroyed by excessive current.

d. Connect the Standing Wave Amplifier to the detector mount.

e. Adjust the RANGE switch and the GAIN control until a full scale indication (0 db) is obtained on the meter.

NOTE

Do not adjust the GAIN control during the remainder of the procedure.

f. Insert the attenuator to be measured between the oscillator and the detector.

g. Adjust the RANGE switch clockwise until an on-scale indication is obtained on the meter.

h. Add the changes in the RANGE switch position to the meter indication (use the 0 to 10 decibel scale) to obtain the attenuation.

i. If the attenuation is less than 2.3 decibles, turn the METER SCALE switch to the EXPAND position and read the attenuation on the 0 to 2.3 decibel scale.

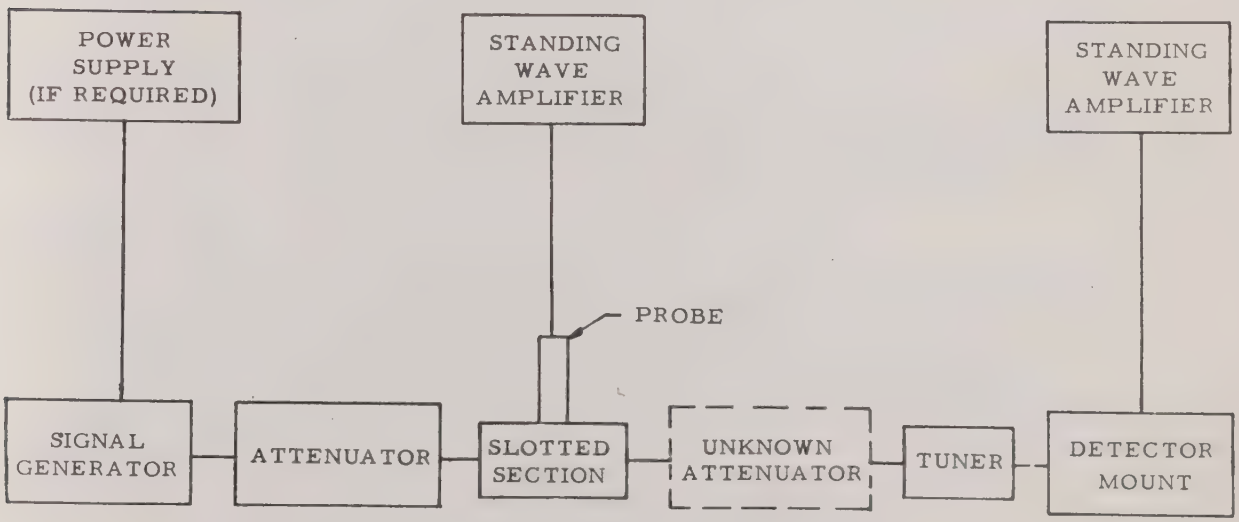

Figure 3. Attenuation Measurement Setup

2.3.6 MEASUREMENT OF BOLOMETER CURRENT

Bolometer current can be read directly on the meter. To measure a bolometer current, place the METER SCALE switch in the BOLO CURR position. The meter should indicate approximately 4.5 or 8.75 MA depending on the position of the INPUT SELECTOR switch. If it fails to do so, the bolometer may be burned out (zero reading on meter) or shorted (greater than rated current).

2.3.7 USING EXTERNAL RECORDER

An external recorder with a 1500 ohm resistive input impedance can be connected to the RECORDER jack. When the recorder is connected, the meter will give the same indication as the recorder. The recorder should be connected by two-conductor shielded cable using Switchcraft No. 480 connector, or equivalent.

SECTION III

THEORY

3.1 CIRCUIT DESCRIPTION

The Model 351 Standing Wave Indicator consists of a high-gain amplifier with very low noise level, a filter, an indicating meter and an electronic regulated power supply.

3.2 FREQUENCY SELECTIVE AMPLIFIER

The frequency selective amplifier consists of a step-up input transformer, T2, four r-c coupled amplifier stages and a fourth stage driving a fixed-frequency filter. The amplifier without the input transformer provides a total gain of 115-db gain, while T2 provides an additional 30 db.

The input circuit to an amplifier is arranged to match various external signal sources such as a crystal diode, barretter or a relatively high-impedance device (bridge circuit, etc.). When the input circuit is switched to 200K ohms, the INPUT jack connects through the RANGE switch, S5, to the grid of the first amplifier stage. In the XTAL-200Ω position, the INPUT jack connects to the primary of T2 which provides a reflected load of 200 ohms to any device connected to the INPUT jack

In the BOLO MA positions, the INPUT jack connects to the primary of the input transformer as above; except that the primary winding is now returned to a current source, R2 and R3, providing d-c operating bias through the transformer winding to any 200 ohm detector element connected to the input jack. Two different values of bias (4.5 and 8.75 milliamperes) may be used. The bias current may be measured directly on the front panel meter when the scale selector is in the bolometer current position.

The RANGE switch, S5, consists of a three section step attenuator, which changes the gain of the amplifier in 10-db steps. However, to obtain square law meter calibration, the steps are calibrated 5 db on the front panel. The three sections of the attenuator are located in the grid circuits of the first three amplifier stages, V1A, B and V2A. The third section provides the first attenuation step and the first section provides the remaining four attenuation steps. Selected precision resistors are used throughout the range switch. Because of the extremely high gain in this amplifier, the grounding of all parts in the first and second stages is very critical and

specially indicated on the schematic diagram. The heavy lines indicate connon negative tie points which in turn are together and connected to chassis only at J1.

The output level from the amplifier is controlled by a two-section potentiometer (GAIN, R22A and VERNIER, R22B.) in the grid circuit of the last amplifier stage. The potentiometers are connected in series, one providing approximately 25 db (12.5 db on the meter scale) of control for coarse adjustments, the other approximately 1.5 db (0.75 db on the meter scale) of control for fine adjustments.

To make the amplifier frequency selective, the plate circuit of the last stage is loaded with parallel resonant circuit, Z1, having an effective Q between 20 and 30. The tuned circuit allows a 1000 cps signal to pass unattenuated, while the decreased impedance at off resonant frequencies attenuates these frequencies considerably. The effective bandwidth is approximately 40 cycles at the half-power points.

3.3 METER CIRCUIT

The 1000 cps signal from the selective amplifier is applied to a two-stage feedback amplifier which operates crystal rectifiers CR1, CR2 and the indicating meter M1. To assure linear operation, negative feedback is used around both the amplifier and the rectifier circuit. A 0.46 volt rms signal is required at the first grid of V3 to obtain a full scale meter indication. The signal from the second plate of V3 is fed to crystal diode CR2 which allows current to flow through R37 and the meter during the negative half of the signal cycle. During the positive half cycle the current returns through CR1 and R36.

Front panel selector S4, when set to the EXPAND position, applies a d-c bucking voltage to the meter rectifiers so that the meter reading is forced off-scale, i.e., downward. The amplifier sensitivity must then be increased to obtain an upscale reading; which can then be read on the expanded meter scales.

3.4 POWER SUPPLY

The power supply consists of a power transformer with a single high-voltage winding feeding a full wave rectifier and electronic voltage regulator supplying d-c to all the circuits of the standing wave indicator. The voltage regulator circuit maintains constant output voltage with wide changes in load current and line voltage.

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V5, V6 and V7 constitute the voltage regulator circuit. V7 is a constant-voltage tube which provides the reference bias for V6. V5 operates as a series tube, or variable resistor, controlled by the voltage at the grid of V6. If the regulated B+ at the cathode of V5 tends to increase, the grid voltage for V6 increases causing V6 to draw more current. This lowers the plate voltage of V6 and therefore the grid voltage of V5 and results in greater plate resistance for V5. The greater plate resistance causes a greater voltage drop across V5, compensating for the increased voltage at its cathode and resulting in a substantially constant voltage output.

If the regulated B+ voltage tends to decrease, the reverse of the above action occurs, also tending to maintain the cathode voltage substantially constant. Ripple in the output voltage is coupled to the grid of V6 by capacitor C12. Variations in the d-c voltage are coupled to the grid of V6 through the voltage divider R44, R45, and R46. The bias for V6 and the level of the output voltage from V5 are determined by the setting of R45.

The heaters of amplifier tubes V1, V2 and V3 are operated from a positive biased heater winding to reduce hum pickup from the heaters of these tubes. The bias voltage is obtained from a 10 volt point on the voltage divider stick R44, R46 and R48 in the power supply.

SECTION IV

MAINTENANCE

4.1 INTRODUCTION

The Model 351 is basically a high-gain, narrow band, tuned amplifier, which feeds into a relative indicating vacuum tube voltmeter. The instrument has few critical circuits. The maximum sensitivity may decrease as the tubes age, but the accuracy of the instrument will not be affected by this. With tube replacement, only adjustment of the power supply or recalibration of the expanded scale is required.

The accuracy of the meter calibration is determined largely by crystal diodes CR1 and CR2. The mechanical tracking of the meter movement and its linearity, as well as the linearity of the amplifier, also affects the meter calibration accuracy to a lesser degree. Normally, the amplifier linearity will not change with time. If the unit displays any instability, this can usually be traced to the power supply. The power supply output can be checked by measuring its d-c output voltage and by noting the noise level indication on the 351 meter. An incorrect output voltage of the power supply and/or high residual noise levels can be corrected by adjustment or by changing tubes. A high residual noise level that cannot be traced to the power supply can usually be corrected by replacing tube V1.

4.2 REPLACING TUBES

The vacuum tubes in the Model 351 canbe replaced without making any adjustments except for those in the regulated power supply. The calibration of the expanded scale should be checked after replacement of tube V3. After changing tubes in the power supply, the output voltage of the supply should be checked and adjusted. To do this, adjust potentiometer R45 to obtain the correct d-c voltage across capacitor C11C.

When replacing the input stage tube V1, select a tube that shows minimum noise and absence from microphonics.

4.3 REPLACING CRYSTAL DIODES

When replacing crystal diodes CR1 and CR2, select diodes with a high front-to-back resistance ratio of several hundred to one or better. Check the calibration of the expanded scale after replacing these components.

4.4 TEST EQUIPMENT REQUIRED FOR TEST AND CALIBRATION OF THE MODEL 351

4.4.1 A one kilocycle audio oscillator or signal generator.

4.4.2 An A-C vacuum tube voltmeter, Ballantine Model 300G or equivalent.

4.4.3 Audio attenuator, General Radio Model 546-C or equivalent.

4.4.4 600Ω to 200Ω Matching pad.

4.4.5 Adjustable line transformer, Powerstat Type 116 or equivalent.

4.4.6 D-c voltmeter, Simpson Model 260 or equivalent.

4.4.7 200Ω 1% resistor.

4.5 TEST AND ADJUSTMENT PROCEDURE

Prior to commencing any test and adjustment of the Model 351 allow a 10 to 15 minute warm up and check the output voltage of the power supply. The procedures that follow below are listed in a sequence that is recommended when a complete test and calibration is intended. In those cases where individual checks are required, they can be done without testing for the other characteristics.

The results of the tests and adjustments described below should be checked against the specifications for the Model 351 Standing Wave Amplifier as given in the front of this manual. Note: The calibration of the Model 351 is based upon the use of square law detectors such as crystals and bolometers. This means that the detector output voltage will vary directly with the r-f input power. To compensate for this characteristic, the Model 351 is calibrated to show a 1 db change on its meter when a 2 db change in voltage is applied to the input. Therefore, each 5 db step on the Model 351 range switch represents a 10 db change in input voltage.

4.6 MECHANICAL ZERO SET OF THE METER

After allowing the instrument to warm up for the period of time recommended above, turn the instrument off and set the mechanical zero of the meter while it is still warm. The correct position of the meter needle with no signal applied is the radial line to the left of the meter marking "1.3" on the upper EXP scale.

4.7 REGULATED POWER SUPPLY ADJUSTMENT

Connect the d-c voltmeter across capacitor C11C. Adjust potentiometer R45 for a voltmeter reading of 245 volts d-c with the line

voltage set to 115 volts. For line voltage variations between 103 and 127 volts, the reading of the voltmeter should not change by more than ± 1%.

4.8 BOLOMETER CURRENT CHECK

Connect the 200 ohm resistor across the INPUT BNC jack and connect the d-c voltmeter across the resistor. With the INPUT SELECTOR switch in the BOLO MA - 4.5 position, the voltage across the resistor should be 0.9 ± 0.07 volts. Switch the METER SCALE selector to the BOLO CURR position. The meter should indicate at the 4.5 milliampere dot. Now turn the INPUT SELECTOR to the BOLO MA - 8.75 position. The voltage across the resistor should be 1.75 ± 0.13 volts. Turn the METER SCALE switch to the BOLO CURR position. The meter should indicate at the 8.75 milliampere dot.

In the event that the voltage across the 200 ohm resistor is incorrest in either of the two positions, check resistors R1, R2 and R3, as well as the power supply output voltage. If the voltage across the 200 ohm resistor is correct, but the meter indication is wrong, adjust potentiometer R54 for the correct reading.

4.9 SENSITIVITY TEST

Connect the test equipment as shown in Figure 4. The a-c vacuum tube voltmeter should be connected to the output of the matching pad. The chassis connection to the Model 351 through the third wire of the power cord should be disabled by using a three prong to two prong polarized adapter. The only ground connection to the 351 must be through the shielded cable from the attenuator set. Rotate the Model 351 GAIN control fully clockwise and the RANGE switch to the 60 db position. Set the INPUT SELECTOR to XTAL-200 Ω position and the METER SCALE selector to the NORMAL position.

Tune the frequency of the audio oscillator for maximum deflection on the Model 351 meter. Adjust the audio oscillator output voltage to obtain full scale deflection on the 351. The reading on the a-c VTVM should be 0.1 volt or less. The sensitivity of the 351 can be calculated by dividing the a-c VTVM meter reading by one million, i.e. when going from 60 to 0 db, the sensitivity of the 351 is increased by 60 db or one million to one. If the sensitivity of the instrument is low, try replacing tubes V1, V2 and/or V3.

4.10 RANGE TRACKING TEST

Connect the equipment as shown in Figure 4. Connect the a-c VTVM to the input of the audio attenuator. Rotate the Model 351 GAIN

control fully clockwise and set the RANGE switch to 0 db, the INPUT SELECTOR to XTAL - 200Ω and the METER SCALE switch to NORMAL.

Adjust the frequency of the audio oscillator for maximum deflection on the 351 meter. Adjust the audio oscillator output voltage for a full scale indication of "0" and the DB scale. Note the reading of the a-c VTVM and adjust the output of the audio oscillator to keep this reading constant during the test procedure that follows.

Add 10 db attenuation in the attenuator and rotate the Model 351 RANGE switch on 5 db step. The Model 351 meter should now read 0 db ± 0.1. Repeat this procedure for each step of the RANGE switch. The meter on the 351 should indicate within ± 0.2 db of the full scale mark on all ranges. Adjacent ranges should read within 0.1 db of each other.

4.11 NOISE LEVEL TEST

Connect the equipment as shown in Figure 4. Connect the a-c VTVM to the output of the matching pad.

Set the Model 351 GAIN control fully clockwise, the RANGE switch to 60 db, the INPUT SELECTOR to XTAL - 200Ω and the METER SCALE selector to NORMAL.

Adjust the audio oscillator frequency for maximum deflection on the 351 meter. Adjust the audio output voltage to obtain a reading of 0.03 volts on the a-c VTVM. Note: Record the reading on any convenient scale of the 351 for reference.

Disconnect the a-c VTVM and the audio oscillator and set the attenuator for maximum attenuation. Rotate the RANGE switch to 0 db. The indication on the 351 meter should be less than, i.e. to the left of, the reference indication noted above.

4.12 EXPANDED SCALE CALIBRATION

Connect the test equipment as shown in Figure 4. Connect the a-c VTVM to the input of the audio attenuator. Set the Model 351 GAIN control fully clockwise, the RANGE switch to 60 db, the INPUT SELECTOR to XTAL - 200Ω and the METER SCALE selector to EXPAND.

Tune the audio oscillator frequency for maximum deflection on the 351 meter and adjust the output of the oscillator to provide a full scale indication. Increase the attenuator setting 4 db and observe the indication on the EXP - DB scale. A reading of 2 db should be obtained. If this reading is not obtained, adjust R33 for a deviation on the other

side of the 2 db mark equal to the error measured above. Return the attenuator to its original position and readjust the output of the oscillator for full scale indication. Repeat the test as necessary until no further adjustment is required.

4.13 NORMAL-EXPAND NORMALIZATION

Connect the test equipment as shown in Figure 4. Connect the a-c VTVM to the input of the audio attenuator. Adjust the Model 351 GAIN control fully clockwise, set the RANGE switch to 60 db, the INPUT SELECTOR to XTAL - 200 Ω and the METER SCALE selector to EXPAND.

Adjust the audio oscillator frequency for maximum indication on the 351 meter. Adjust the oscillator output voltage to provide a full scale indication, switch the METER SCALE selector to NORMAL and adjust potentiometer R53 for a 0 db reading. Return the METER SCALE selector to the EXPAND position. The meter should still indicate 0 db. Repeat this test as necessary until the readings in the two positions of the METER SCALE selector are the same.

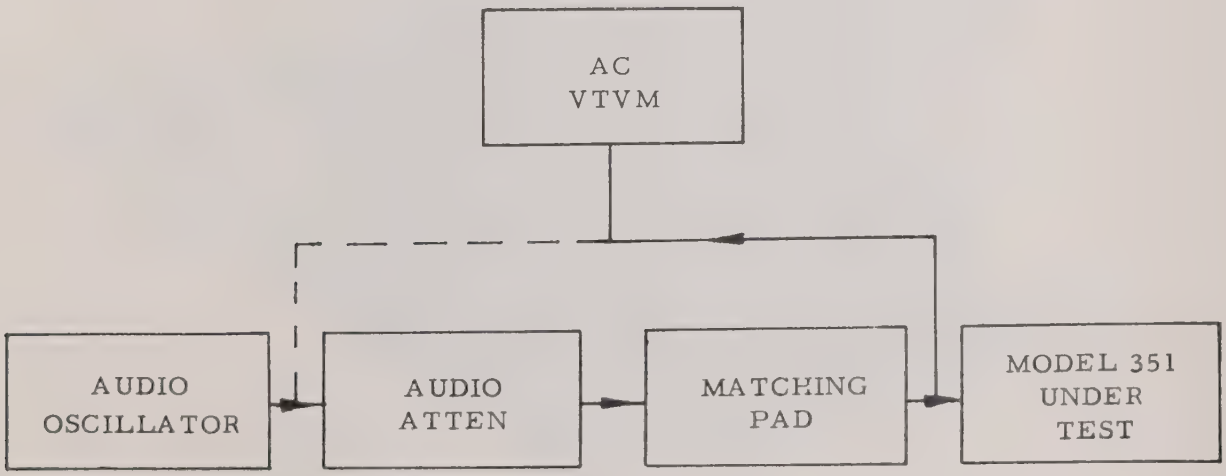

Figure 4. Block Diagram Of Test Set-Up

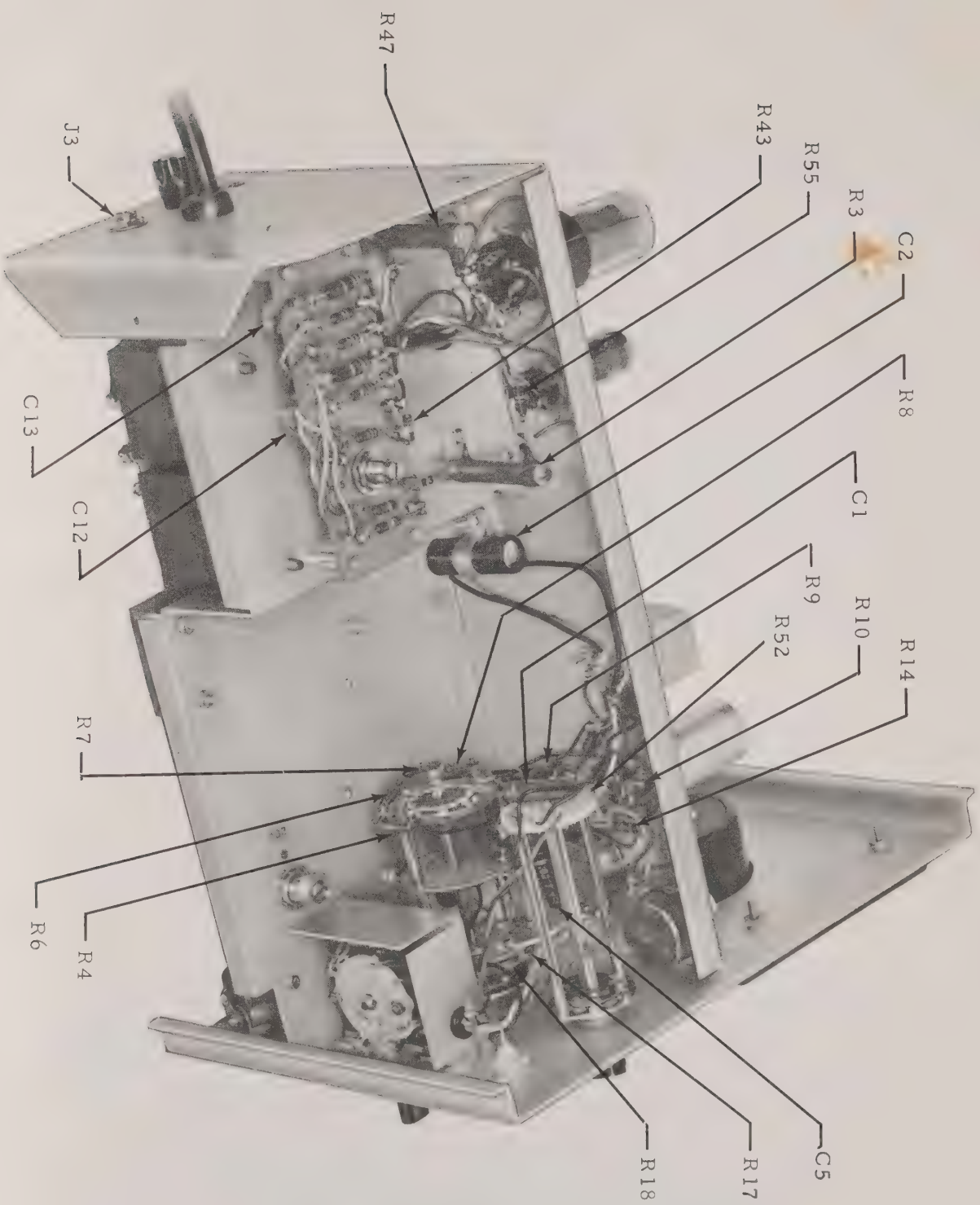

FIGURE 5 LEFT SIDE VIEW WITH COVER REMOVED

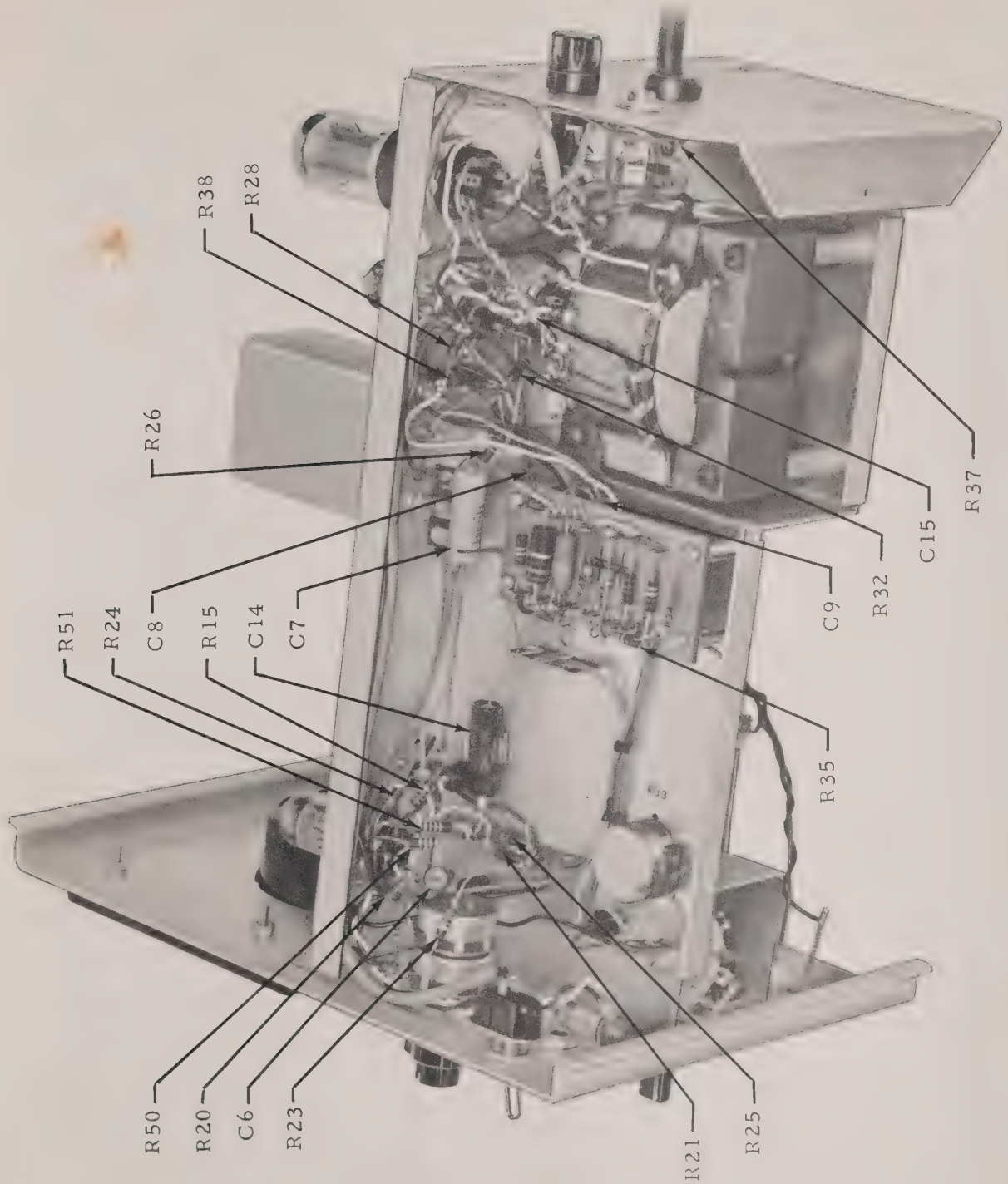

FIGURE 6 RIGHT SIDE VIEW WITH COVER REMOVED

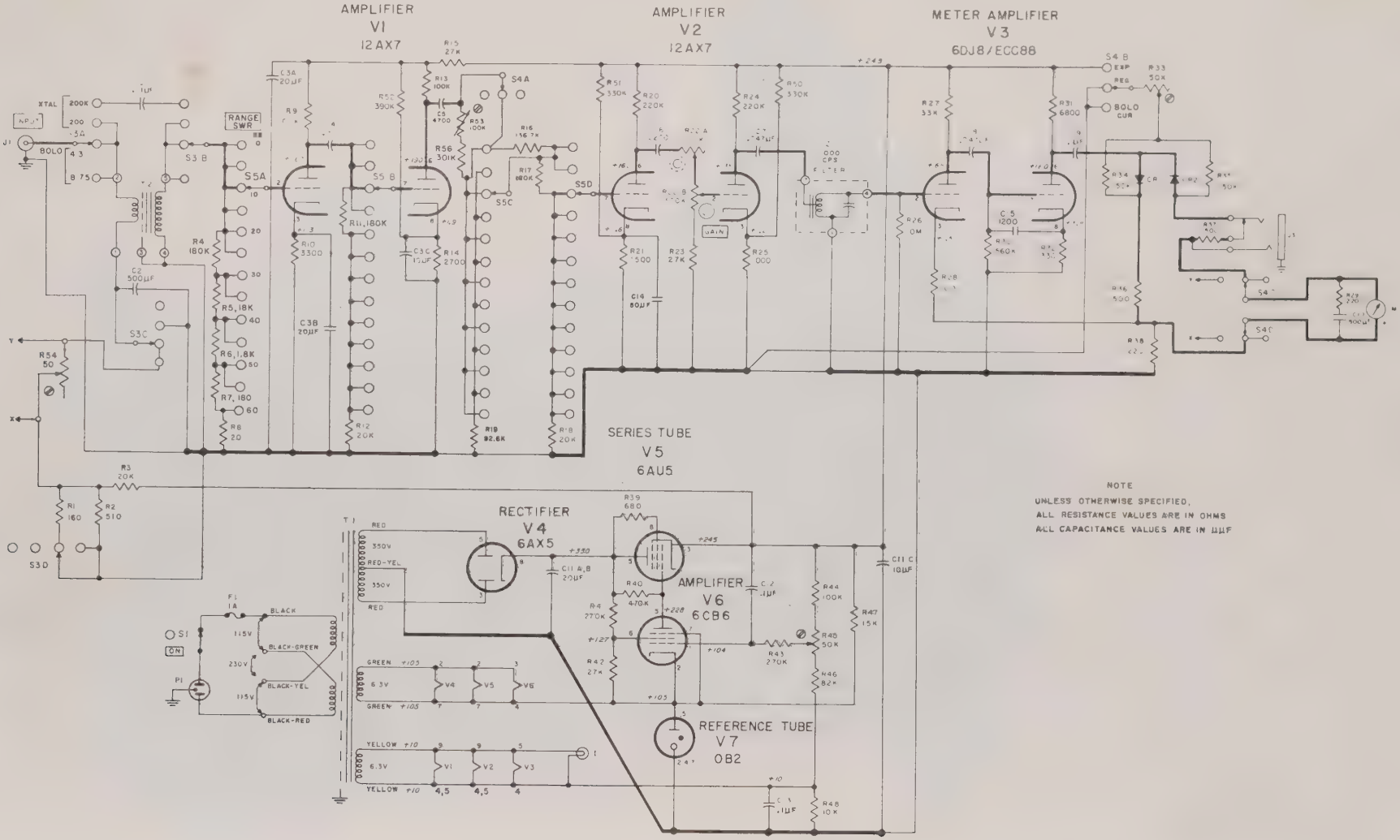

Figure 7 Model 351 Standing Wave Indicator

SECTION IV

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION	TOTAL NO. USED	MFRS. CODE	GMC DWG. NO.
C1	Capacitor: fixed, paper, 01 µf ±10%, 400 vdcw	1	M	
C2	Capacitor: fixed, electrolytic, 500 µf, 15 vdcw	2	F	
C3 A, B, C	Capacitor: fixed, electrolytic, 3 sections, 20 µf/sect., 250 vdcw	1	F	
C4, 5	Capacitor: fixed, paper .0047 µf ± 10%, 400 vdcw	2	M	
C6	Capacitor: fixed, paper, .0022 µf ± 10%, 400 vdcw	1	M	
C7, 8	Capacitor: fixed, paper, .047 µf ±10%, 400 vdcw	2	M	
C9	Capacitor: fixed, paper, 0.1 µf ± 10%, 400 vdcw	3	M	
C10	This ref. sym. not assigned	1	P	
C11 A, B, C	Capacitor: fixed, electrolytic, 3 sections, 10 µf/sect., 400 vdcw	1	F	
C12, 13	Same as C9			
C14	Capacitor: fixed, electrolytic, 50 µf, 3 vdcw	1	F	
C15	Capacitor: fixed, disc cermanic, 1200 pf, ± 20% 500 vdcw	1	P	
CR1, 2	Rectifier, crystal: germanium diode, IN277	2		

CIRCUIT REF.	DESCRIPTION	TOTAL NO. USED	MFRS. CODE	GMC DWG. NO.
F1	Fuse, cartridge: 1 amp, slo-blo for 115 V operation	1	K	
	Fuse, cartridge: 1/2 amp. for 230 V operation	1	K	
I1	Lamp, incondescent: 6-8 V, .15 amp, #51	1	H	
J1	Connector, receptacle: UG-1094/U	1	B	
J2	Jack, telephone: for 3 conductor plub, type 13B	1	N	
M1	Meter: dc milliammeter	1		1845
R1	Resistor: deposited carbon 165 ohms±1%, 1/2 W	1	J	
R2	Resistor: deposited carbon 549 ohms ± 1%, 1/2W	1	J	
R3	Resistor: fixed, wirewound 20,000 ohms ± 5%, 10 W	1	R	
R4	Resistor: fixed, deposited carbon, 180,000 ohms ± 1%, 1/2 W	3	J	
R5	Resistor: fixed, deposited carbon, 18,000 ohms ± 1%, 1/2 W	1	J	
R6	Resistor: fixed, deposited carbon, 1800 ohms ± 1%, 1/2 W	1	J	

CIRCUIT REF.	DESCRIPTION	TOTAL NO. USED	MFRS. CODE	GMC DWG. NO.
R7	Resistor: fixed, deposited carbon, 180 ohm ± 1%, 1/2 W	1	J	
R8	Resistor: fixed, deposited carbon, 20 ohms ± 1%, 1/2 W	1	J	
R9	Resistor: fixed, deposited carbon, 100,000 ohms ± 1%, 1/2 W	3	J	
R10	Resistor: fixed, composition, 3300 ohms ± 10%, 1/2 W	1	J	
R11	Same as R4			
R12	Resistor: fixed, deposited carbon, 20,000 ohms ±1%, 1/2 W	2	J	
R13	Same as R9	2	J	
R14	Resistor: fixed, composition, 2700 ohms ± 10%, 1/2 W	1	J	
R15	Resistor: fixed, composition 27,000 ohms ± 10%, 1/2 W	3	J	
R16	Resistor: fixed, deposited carbon, 136,700 ohms ± 1%, 1/2 W	1	J	
R17	Same as R4			
R18	Same as R12			

CIRCUIT REF.	DESCRIPTION	TOTAL NO. USED	MFRS. CODE	GMC DWG. NO.
R19	Resistor: fixed, deposited carbon, 92,600 ohms ± 1%, 1/2 W	1		
R20	Resistor: fixed, composition, 220,000 ohms ± 10%, 1/2 W	3		
R21	Resistor: fixed, composition, 1500 ohms ± 10%, 1/2 W	3		
R22, A,B	Resistor: variable, composition, dual section front sect., 500,000 ohms rear sect., 100,000 ohms	1		1709
R23	Same as R15			
R24	Same as R20			
R25	Resistor: fixed, composition, 1000 ohms ± 10%, 1/2 W	1	J	
R26	Resistor: fixed, composition, 68,000 ohms ± 10%, 1/2 W "Electrical value adjusted at factory"	1	J	
R27	Resistor: fixed, composition, 33,000 ohms ± 10%, 1 W	1	J	
R28	Resistor: fixed, composition, 100 ohms ± 10%, 1/2 W	1	J	

CIRCUIT REF.	DESCRIPTION	TOTAL NO. USED	MFRS. CODE	GMC DWG. NO.
R30	Resistor: fixed, composition, 560,000 ohms ± 10%, 1/2 W	1	J	
R31	Resistor: fixed, composition, 6800 ohms ± 10%, 2 W	1	J	
R32	Resistor: fixed, composition, 330 ohms ± 10%, 1/2 W	1	J	
R33	Resistor: variable, composition, linear taper, 50,000 ohms ± 20%	2	E	
R34, 35	Resistor: fixed, composition, 150,000 ohms ± 10%, 1/2 W	2	J	
R36, 37	Same as R21			
R38	Resistor: fixed, composition, 220 ohms ± 10%, 1/2 W	1	J	
R39	Resistor: fixed, composition, 680 ohms, ± 10%, 1W	1	J	
R40	Resistor: fixed, composition, 470,000 ohms ± 10%, 1/2 W	1	J	
R41	Resistor: fixed, composition, 270,000 ohms ± 10%, 1/2 W	2	J	
R42	Same as R15			

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CIRCUIT REF.	DESCRIPTION	TOTAL NO. USED	MFRS. CODE	GMC DWG. NO.
R43	Same as R41			
R44	Same as R9			
R45	Same as R33			
R46	Resistor: fixed, composition, 82,000 ohms ± 10%, 1/2 W	1	J	
R47	Resistor: fixed, wirewound, 15,000 ohms ± 10%, 10W	1	R	
R48	Resistor: fixed, composition, 10,000 ohms ± 10%, 1/2 W	1	J	
R49	This ref. sym. not assigned	1		
R50, 51	Resistor: fixed, composition, 330,000 ohms ± 10%, 1/2 W	2		
R52	Resistor: fixed, composition, 390,000 ohms ± 10%, 1/2 W	1		
R53	Resistor: variable, composition, linear taper, 100,000 ohms ± 20%	1	E	
R54	Resistor: variable, wirewound, linear taper, 50 ohms ± 10%	1	E	
R55	Same as R20			
R56	Resistor: fixed, deposited carbon 301,000 ohms ± 10%, 1/2 W	1	G	
S1	Switch, toggle: SPST			

CIRCUIT REF.	DESCRIPTION	TOTAL NO. USED	MFRS. CODE	GMC DWG. NO.
S3	Switch, rotary: 4 positions	1		1705
S4	Switch, lever: 3 positions	1		1706
S5	Switch, rotary: 13 positions	1		1681
T1	Transformer, power	1		1704
T2	Transformer, input	1		1707
V1, 2	Tube, electron: 12AX7	2	O	
V3	Tube, electron: 6DJ8/ECC88	1	S	
V4	Tube, electron: 6AX5GT	1	O	
V5	Tube, electron: 6AU5GT	1	O	
V6	Tube, electron: 6CB6	1	O	
V7	Tube, electron: OB2	1	O	
Z1	Circuit, tuned: 1000-cycle filter	1		1711

LIST OF MANUFACTURER'S CODE LETTERS

Code Letter	Manufacturer	Address
A	Amperite Co.	New York, N. Y.
B	Amphenol Connector	Chicago, Ill.
C	Arco Electronics, Inc.	New York, N. Y.
D	Carling Electric, Inc.	Hartford, Conn.
E	Clarostat Manufacturing Co.	Dover, N. H.
F	Cornell-Dubilier Electric Corp.	Plainfield, N. J.
G	Dale Products, Inc.	Columbus, Nebr.
H	General Electric Co.	Schenectady, N. Y.
I	General Microwave Corp.	Farmingdale, N. Y.
J	International Resistance Co.	Philadelphia, Pa.
K	Littlelfuse, Inc.	Des Plaines, Ill.
L	Marstan Electronics Corp.	New York, N. Y.
M	Sprague Electric Co.	North Adams, Mass.
N	Switchcraft, Inc.	Chicago, Ill.
O	Tung-Sol Electric Co.	Newark, N. J.
P	Erie Resistor Co.	Erie, Pa.
R	Tru-Ohm Products	Chicago, Ill.
S	Amperex Electronics Corp.	Hicksville, N. Y.
T	Sylvania Electric Corp.	Woburn, Mass.

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